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NORTH FORK ALLUVIAL DECONTAMINATION PROJECT, HUBBARD CREEK RESERVOIR WATERSHED

Billy L. Jacob

West Central Texas Municipal Water District

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An evaluation of the project indicated that contaminated water from alluvial deposits can successfully be collected and disposed of. Decontamination of the alluvial deposits was determined to be at a very slow rate, and would take years to show significant improvement. No appreciable reduction in chlorides in the reservoir resulted from the three years operation of the project. (EPA)

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April 1974

NORTH FORK ALLUVIAL DECONTAMINATION PROJECT
HUBBARD CREEK RESERVOIR WATERSHED

By

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Project 14020 EHW
Program Element 1B2040

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ABSTRACT

A detailed demonstration project was performed to determine the effect that dewatering of a polluted alluvial aquifer and subsequent recharge by rainfall would have on the decontamination rate of the polluted alluvium. The alluvial deposits within the project area were polluted by years of brine water disposal from oil field operations into unlined earthen pits, secondary oil recovery operations, and abandoned and improperly plugged oil wells. Secondary benefits of the project were to determine the effect that removal of contaminated alluvial water would have on downstream water quality, and on the quality of water in a municipal water supply located downstream from the project site. Contaminated water withdrawn from the alluvium was disposed of in a deep disposal well having a depth of 5,700 feet.

An evaluation of the project indicated that contaminated water from alluvial deposits can successfully be collected and disposed of. Decontamination of the alluvial deposits was determined to be at a very slow rate, and would take years to show significant improvement. No appreciable reduction in chlorides in the reservoir resulted from the three years operation of the project.

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CONTENTS

		Page
Abstract		ii
List of Figures		iv
List of Tables		v
Acknowledgements		vi
Sections		
I	Conclusions	1
II	Recommendations	3
III	Introduction	4
IV	Background Salt Water Pollution Investigations	6
V	Purpose of Project and Project Objectives	10
VI	Description of Installation and Operation of Decontamination Project	14
VII	Monitoring and Testing	28
VIII	Projection Discussion	31
IX	References	49

FIGURES

No.		Page
1	Location Map	13
2	Project Layout	15
3	Diagramatic Illustration of Water Injection Well	18
4	Typical Detail of Collection Sump	20
5	Location of Observation Wells	22
6	Location of U. S. G. S. Monitoring Stations	29
7	Weighted Average Monthly Chlorides in Sumps No. 1, 3 & 4	35
8	Relationship Between Flow in Hubbard Creek and Chloride Content	47

TABLES

No.		Page
1	Observation Well Data	23
2	Typical Chloride Content of Samples from Observation Wells	26
3	Record of Pumpage from Collection Sumps	32
4	Monthly and Yearly Precipitation for the Project Area	36
5	Summary of Project Data	38
6	Annual Chloride and Dissolved Solids Loadings (U.S.G.S. Station 8-0861.50)	41
7	Annual Chloride and Dissolved Solids Loadings (U.S.G.S. Station 8-0862.12)	42
8	Annual Chloride and Dissolved Solids Loadings (U.S.G.S. Station 8-0861.0)	42
9	Chloride Content of Hubbard Creek Reservoir	46

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The work performed on investigational studies by Conselman, Jenke and Tice, Consultants, and Conselman, Jenke Associates, Consultants to the Water District on investigational studies and during project development and construction, from which considerable information was used in this final report, is particularly acknowledged.

Assistance from the United States Geological Survey, in providing records of flows and water quality to the Water District, was substantial in the project evaluation.

Assistance given to the author by the staff personnel of the West Central Texas Municipal Water District, during completion of the final report, is appreciated.

The operation and maintenance of project facilities was performed by Mr. Roy Matthews. During most of the project period, the project was under the directorship of Mr. Austin P. Hancock, who was manager of the West Central Texas Municipal Water District. After Mr. Hancock's retirement from the District in September 1971, the project was directed by Mr. Victor Jaeggli, who is the present manager of the District.

SECTION I

CONCLUSIONS

This demonstration project, on the removal of contaminated groundwater from alluvial deposits and subsequent decontamination by natural fresh water recharge, has led to the following conclusions:

The alluvial material, located in the North Fork of Hubbard Creek, can successfully be dewatered by construction of collection sumps, or trenches, and pumping systems.

Contaminated water can successfully, and with relative ease, be disposed of by subsurface injection into deep, highly saline formations.

Continuity of the alluvial material, along North Fork of Hubbard Creek, does not exist; consequently, contaminated water does not flow freely within a common alluvium for the length of the drainage basin.

Rate of decontamination of the alluvium, upon dewatering will be at a very slow rate and would occur over a period of many years.

Chloride content of water withdrawn from the alluvium was considerably lower than expected; consequently, the effect of removal of contaminated waters on downstream water quality, and on the quality of water in Hubbard Creek Reservoir, was insignificant.

The effect of chloride concentrations in the North Fork alluvial waters have little effect on the quality of water in Hubbard Creek Reservoir as compared to the effect by evaporation and transpiration.

The chloride concentrations that are deposited on or near the surface of the topsoil, or alluvial deposits, and the storage of water with high chloride content in the stream beds have a significant effect on the quality of initial runoff from the watershed.

The cooperative action of the Railroad Commission of Texas, oil operators, and the Water District which brought about improved methods of secondary oil recovery operations, brine water disposal, plugging of abandoned oil wells, and the elimination of surface storage pits, appear to be the major influence in water quality improvements within the drainage basin of North Fork and Cook Creeks since 1966. These activities were stimulated significantly by the initiation and conduct of this project.

SECTION II

RECOMMENDATIONS

Experience that the West Central Texas Municipal Water District has gained during this demonstration project could be valuable to other areas facing the problem of salt water contamination of water supplies. Specific recommendations are:

Contamination of alluvial deposits by sodium chloride occurs frequently across the United States in either a small centralized area or on a more regional basis. Efforts to decontaminate such alluvial deposits, or otherwise reduce the encroachment of contaminated waters on a more widespread basis, would be more successful if observation and test wells, similar to those constructed in this project, were installed prior to project initiation. Step drawdown aquifer tests could be performed during the time of observation well installation to determine the expected yield from the alluvium. Small yields and low chloride concentrations would probably indicate non-productive decontamination efforts.

Efforts that have been made in the cleanup of surface pollution should be continued by both the West Central Texas Municipal Water District and the oil industries operating within the Hubbard Creek watershed.

Water-quality and water-quantity data that have been obtained demonstrates that water entering the Hubbard Creek Reservoir during low flows is high in dissolved solids, especially chlorides. A substantial amount of the low flows are from subsurface infiltration waters. Water-quality data further demonstrates that after the initial wash off of the watershed, high flow runoff is relatively free from such dissolved solids.

It is possible that through weather modification operations, runoff can be increased significantly and thereby improve the quality of flows into Hubbard Creek Reservoir.

SECTION III

INTRODUCTION

The West Central Texas Municipal Water District was organized under Charter from the State of Texas to construct Hubbard Creek Reservoir, located in Stephens County, Texas, for the purpose of providing municipal water for the cities of Abilene, Albany, Anson, and Breckenridge. Each of these cities is a member of the WCTMWD and each has a direct interest in the quality of water from the reservoir, since presently or in the future, they will depend upon the reservoir to meet a portion or all of their municipal and industrial water demands. To date, the City of Breckenridge is the only customer that has utilized water from Hubbard Creek for municipal purposes. This use was begun in 1972 when Lake Daniel, the historical water supply for the city, became dry.

Construction of Hubbard Creek Reservoir was begun in 1961 and construction for the dam, emergency spillway, and outlet works was completed in 1962. Initial impoundment of water began in September 1962. Conservation storage pool of the reservoir was filled in May 1969. The reservoir is located in the Brazos River Drainage Basin.

Hubbard Creek Reservoir receives its runoff from a watershed containing an approximate drainage area of 1,078 square miles. The watershed is situated in portions of Callahan, Eastland, Shackelford and Stephens Counties. The two principal tributaries are Hubbard Creek, draining the area to the west and southwest of the reservoir and Big Sandy Creek, draining the area predominately south and southwest of the reservoir.

The watershed of Hubbard Creek Reservoir is unique in nature in the sense that it includes one of the most heavily drilled oil and gas areas of the United States. Over 13,000 wells are known to have been drilled in the watershed throughout the oil-producing history, dating back to the early 1920's. In addition to the oil and gas wells that have been drilled within the watershed, numerous seismograph shot holes and core holes have also been drilled. There are no historical records available to indicate the actual number, location, or depths to which most of these seismograph holes were drilled.

Many of the wells that were and are presently used for oil and gas production are relatively shallow well productions.

One of the typical by-products associated with the production of oil in this part of West Texas has been the production and recovery of brine water. Since there has been no commercial market for the brine it was disposed into surface watercourses during the early years of oil production in the area. Eventually, it was disposed into unlined surface pits. Each of these disposal methods allowed substantial volumes of highly saline water to percolate into the subsoil and shallow subsurface alluvial deposits.

Compounding the problem of brine-water recovery associated with the production of oil, was the increasing trend toward waterflooding. As the quantity of oil becomes depleted in a field, secondary oil recovery, by waterflooding, is being utilized more frequently by many operators. This involves the re-injection of water into the oil-bearing formation, at high pressures and in a manner to concentrate the oil into an area making recovery possible. Investigations by Conselman, Jenke & Tice,[1,2] and Conselman, Jenke Associates,[3] have shown that in areas of "careless" secondary oil recovery operations leakage occurs and highly concentrated brine water is discharged into surface watercourses, or into shallow alluvial soils, by means of natural geologic outlets provided by fracturing or faulting of the overlying rocks, variations in overburden pressure produced by topographic relief, and by man-made outlets created earlier by exploration and production activities. Chlorides that have been deposited on the surface, and in alluvial deposits in the Hubbard Creek watershed by previous years of "careless" salt water disposal methods, are transported to the reservoir by low flows brought about by subsurface water seepage and by wash off of the watershed during rainstorms. Concentrations of chlorides in the runoff waters into Hubbard Creek Reservoir were recognized during the early stages of construction of the lake by the Water District and prompted several hydrological investigations to be performed to determine the extent of salt pollution within the watershed of the reservoir.

These earlier investigations eventually became the basis for the North Fork Alluvial Decontamination Project.

SECTION IV

BACKGROUND SALT WATER POLLUTION INVESTIGATIONS

Available data concerning the historic quality of water from the watershed of Hubbard Creek Reservoir was limited prior to 1961. Quality data of flows measured near the dam site, however, indicated that chlorides were 50 to 300 milligrams per liter (mg/l).

In early 1961, the Water District became concerned about the quality of water to be stored in the reservoir and engaged the firm of Conselman, Jenke & Tice, Consulting Geologists, Hydrologists, and Engineers, Abilene, Texas, to conduct investigations within the watershed for the purpose of locating sources of salt pollution and presenting general recommendations to enhance the quality of water that is discharged into the reservoir. During this period of time, the Texas Railroad Commission, United States Geological Survey, and other State and local agencies began a concentrated program of water-quantity and water-quality analysis within the watershed. Also during this period of time, the Consulting Engineering firm of Freese, Nichols and Endress of Fort Worth, Texas, was performing a chloride routing study for the reservoir and reported on June 14, 1962, that, "the chloride contamination in Hubbard Creek, in times of drought, would lead to chloride concentrations in Hubbard Creek Reservoir higher than the limit of 250 part per million (ppm) recommended by the U. S. Public Health Service." Recommendations to the District were to take the necessary measures to control man-made pollution on the watershed, with the goal of lowering the average chloride content of the runoff to 50 ppm or less.

In the report prepared by Conselman, Jenke & Tice,[2] many aspects of salt water contamination were presented including geological formations, effects of industrial oil and gas development on water quality within the watershed, and analyses showing the chloride concentration at various points within the watershed area. Conclusions reached in the report were that chief sources of abnormal chlorides were industrial brine produced in connection with oil and gas operations and that the industrial brines reached the watershed from: "(1) surface leakage of salt water pits, producing wells, water injection wells, lease lines, tanks, heaters, treaters, and abandoned dry holes, (2) leaching of salt-impregnated areas by

runoff, (3) seepage from salt water pits into the shallow subsurface, (4) subsurface seepage from salt water disposal wells pumping brine into the annulus, with pressures and volumes in excess of the capacity of subsurface reservoirs, (5) waterflood injection wells which unintentionally inject brine into reservoirs other than those to be re-pressured, (6) abandoned shot holes and core holes which receive lateral salt water migration from other sources, and (7) occasional, deliberate disposal of brine by dumping into surface watercourses."[2]

Significant importance to water quality of the reservoir in the reports by Conselman, Jenke & Tice, was in the projections which, although based on meager information, indicated that the chloride residual expected in the lake waters would approach 260 mg/l during the first ten years of reservoir life. The report by Conselman, Jenke & Tice, specifically mentioned eighty-six (86) problem areas of salt water pollution within the watershed area.

The general problems of salt water contamination in the reservoir watershed as presented by Conselman, Jenke & Tice, and the chloride routing study by Freese, Nichols and Endress, prompted the District into further investigational studies. Conselman, Jenke Associates, Geologists, Hydrologists and Engineers, Abilene, Texas, made additional investigations on the extent of chloride pollution within the watershed and efforts of their work was presented in their "Report of Investigations; Hubbard Creek Reservoir Watershed, West Central Texas Municipal Water District", in January 1966.

In the 1966 report by Conselman, Jenke Associates, efforts were directed more specifically to the critical areas of salt water pollution that had been established in the earlier reports. It was found that Hubbard Creek and its tributaries, consisting of: North Fork, Cook Creek, Salt Prong, Jeter Draw, Cruddy Creek, Getright Draw, Matthews Branch, Humble Dam area, and Snailum Creek were the most significant in the chloride pollution of the reservoir.

Results of water-quality monitoring in the reservoir, as presented in the report, indicated that highest chloride residual in the lake was on August 22-23, 1964, amounting to 198 mg/l, at a time when the lake level was relatively low. The lowest chloride residual of 86 mg/l was observed on May 31, 1965, immediately after a major

inflow which more than tripled the lake volume. Chloride content in December 1965, was about 116 mg/l.

Results of unpublished records prepared by the U. S. G. S. indicated that chloride pollution was distributed unequally throughout the watershed with the greatest concentrations of chlorides being found in the North Fork-Cook Creek-Salt Prong subdivision. The data presented by Conselman and Jenke showed that for the period February 1, 1962, to May 31, 1965, this drainage area represented 13 percent of the upper drainage area and produced 38 percent of the total chlorides, while flows for the area represented only 9 percent of the total water discharge measured at the Hubbard Creek below Albany monitoring station. Further significance of pollution in the North Fork valley was presented from reports of the U. S. Geological Survey, which indicated that of the total chloride increment entering the reservoir during the period October 1, 1963, to May 31, 1965, 25. 7 percent of the chlorides came from the North Fork valley west of Albany, which produced only 3. 4 percent of the water discharge.

In discussion of watershed contamination factors, Conselman and Jenke noted that the valleys of all the streams in the watershed contained various amounts of alluvial fill, which in most instances was contaminated with varying amounts of residual chlorides and brine water.

An interesting experiment that was being performed at that time by an oil operator was noted in their report. The oil operator had constructed a sump in the alluvium valley of Cook Creek and had installed a suction system which permitted the removal of collected water from the sump for injection into a depleted underground reservoir. The system had been in operation for approximately five (5) months, and the operator reported a cumulative injection of 18, 584 barrels of groundwater, which, during the month of December 1965, averaged 4, 275 mg/l of chlorides. This amounted to approximately twenty-three (23) tons of salt equivalent diverted from the reservoir, if based on the assumption that all of the groundwater ejected would have eventually found its way to the surface watercourse and into the reservoir.

Recommendations by Conselman, Jenke Associates, [3] as presented to the Water District in 1966, was in part: "... The District should

install, as promptly as funds and circumstances permit, a series of water disposal systems in contaminated alluvial areas, where pollution has already accumulated in amounts too extensive to be acceptable in the reservoir, and where no other party can be considered responsible. These areas include:

a. North Fork at Albany
b. Humble Dam
c. South Eolian
d. West Moran
e. Snailum Creek (?)

Some of these systems may be installed when the opportunity exists for doing so at minimum expense, as by acquiring a suitably located dry hole or abandoned producer for use as a disposal well. However, the Albany sump and disposal system should not be deferred..."

SECTION V

PURPOSE OF PROJECT AND PROJECT OBJECTIVES

PURPOSE OF PROJECT

In semiarid regions, such as is the location of this project site, large impoundments of water are necessary in order to obtain reservoirs capable of producing dependable yields. The reservoir must store water for long periods of time to maintain yield projections during extended drought periods; consequently, water quality of the reservoir is subject to degradation brought about by the effects of evaporation and transpiration. The quality of water stored in reservoirs constructed under these conditions will fluctuate and is largely dependent on the elements of time, quality of inflow, quantity of inflow, quality and quantity of outflow, and usage from the reservoir.

At the beginning of this demonstration project, the only beneficial use of water from the reservoir was in small quantities for irrigation. Evaporation and transpiration accounted for substantially all consumptive use from the reservoir. The resultant residual chlorides increased the chloride concentration of the reservoir. Chloride problems in Hubbard Creek Reservoir, therefore, are a result of high evaporation rates in conjunction with inflows of relatively high chloride concentrations and small amounts of usage.

The investigations of chloride contamination on the Hubbard Creek watershed by Conselman, Jenke & Tice, and Conselman, Jenke, Associates, located many areas of the watershed that were responsible for the chloride pollution of Hubbard Creek Reservoir. The magnitude of chloride contamination problems in the watershed and the prediction that chloride contamination could eventually make the reservoir unfit for use, insofar as the then existing U.S. Public Health Service recommendations for chloride concentrations were concerned, caused the Water District to initiate methods for combating the chloride problem.

The major problem areas of chloride pollution were determined to lie within the Hubbard Creek arm of the watershed and, as pointed out by Conselman and Jenke, [3] three major technical problems needed to be solved if inflow to Hubbard Creek Reservoir was to be re-

duced to 50 mg/l. These were: "(1) cleaning up or draining contaminated alluvial material, which contains brine spillage accumulated over the years, (2) preventing new pollution from entering the watershed, and (3) fixing responsibility and arresting contamination when it occurs."

As a result of the investigations and analyses presented to the Water District, the decision was made to attack the chloride pollution problem from the standpoint of arresting pollution caused by low flows containing high chloride concentrations. Most of these highly saline low flows were the result of subsurface seepage.

The purpose of the North Fork Alluvial Decontamination Project, was to decrease the problem of chloride pollution of Hubbard Creek Reservoir caused by seepage from alluvium deposits located in the North Fork of Hubbard Creek.

PROJECT OBJECTIVES

The valley of North Fork, west of Albany, contains approximately 3,089 acres, much of which is underlain by varying thicknesses of alluvial sands, gravels, silts, and clays. The alluvial deposits represent sources for storage of groundwater that has been contaminated by chlorides from saline inflow resulting from oil field operations. Part of the chlorides, within the alluvium and groundwater, infiltrate into the surface watercourses and are carried downstream to Hubbard Creek Reservoir.

The amount of contaminated water that is discharged from the alluvium is not known; however, prior to the beginning of the project, it was believed that flow from the alluvium was of considerable amount and that the chloride content, expressed in milligrams per liter, would be substantial.

Primary objective of the project was to demonstrate the procedure for removal of contaminated water from the alluvial deposits and the disposal of the polluted water by injection into a deep disposal well. Data of chloride concentrations in waters of the alluvium was obtained to provide information on the rate of decontamination of the alluvium by natural recharge.

Location of the Decontamination Project was selected to be on the

North Fork of Hubbard Creek near Albany, Texas, in Shackelford County, because of the historic inferior water contributed by this drainage area. Location of the project area, and its relation to Hubbard Creek Reservoir, is shown in Figure 1.

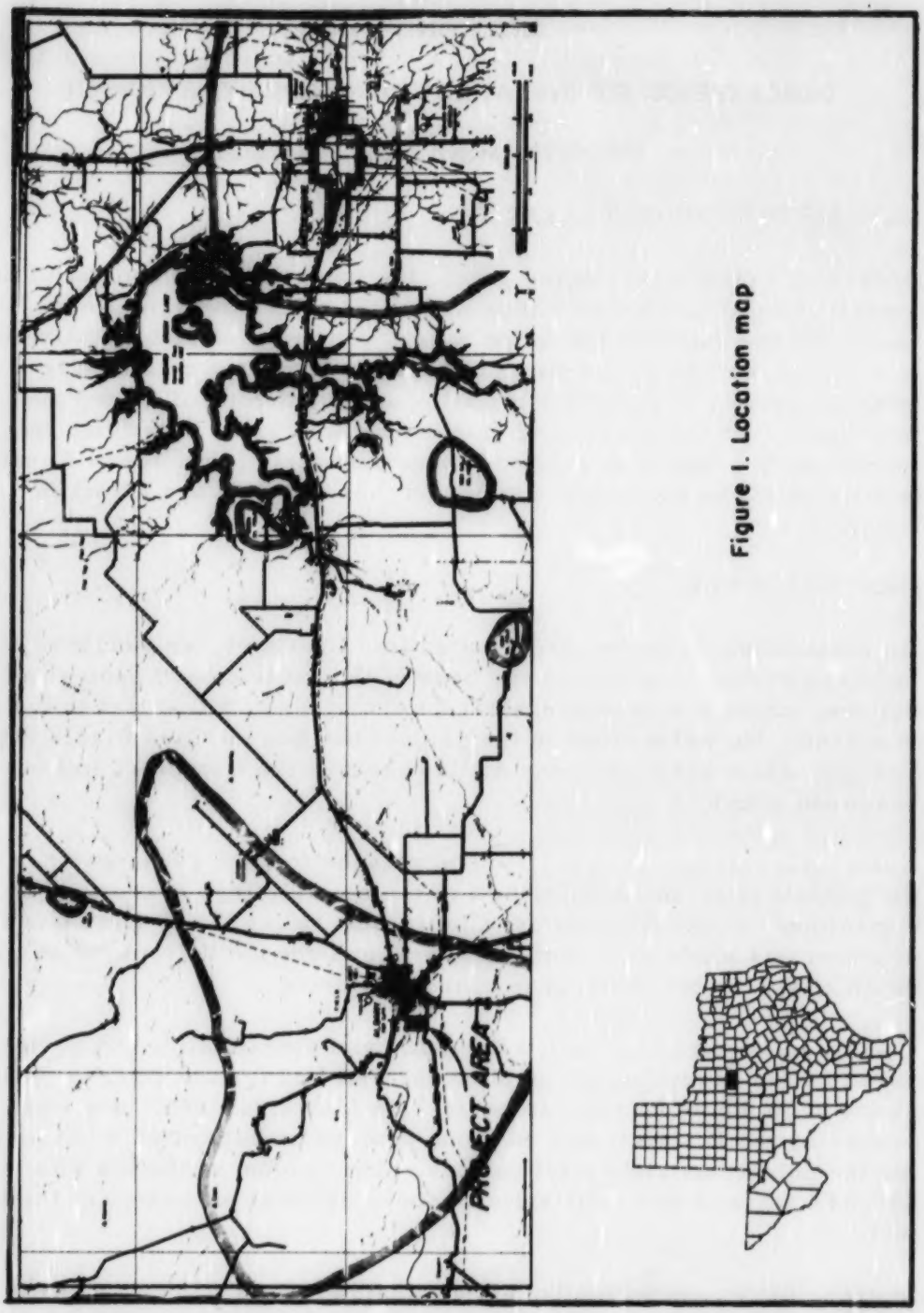

Figure 1. Location map

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SECTION VI

DESCRIPTION OF INSTALLATION AND OPERATION OF DECONTAMINATION PROJECT

DESCRIPTION OF INSTALLATION

According to the terms of the grant, the project was to consist of the construction of collection sumps within the alluvium of the North Fork valley for the collection of brine water; construction and installation of a piping and pumping system to carry brine water collected to a holding reservoir; and the completion and furnishing of a deep well with pump, for the purpose of disposing of the brine water into the Cambrian Greensand at a depth of approximately 5,700 feet. Location and layout of the collection sumps and disposal well are shown in Figure 2.

DISPOSAL WELL

Disposal of the collected brine water into the Cambrian sandstones required access to strata at the base of the sedimentary geological column, which are encountered at depths of about 6,000 feet in the project area. No wells close to the project had been drilled to this depth, and only a few wells had been drilled through the Cambrian and into basement rocks.

A dry well that had been drilled and plugged in June 1966, was near the project site, and upon review of the electric logs of the well by Conselman, Jenke Associates, Consultants to the Water District, the decision was made to re-enter the well and deepen it from the original depth of 4,710 feet to the base of the Cambrian.

Conditions of the grant called for plans and specifications to be prepared on the deepening of the disposal well and for the contract to be awarded on a competitive bid basis. On March 4, 1969, bids were opened by the District, and only one contractor submitted a bid meeting the conditions and specifications. The amount of the bid was $86,543.60, and was substantially above original estimates of the project.

In order to remain within budget estimates for the project, negotia-

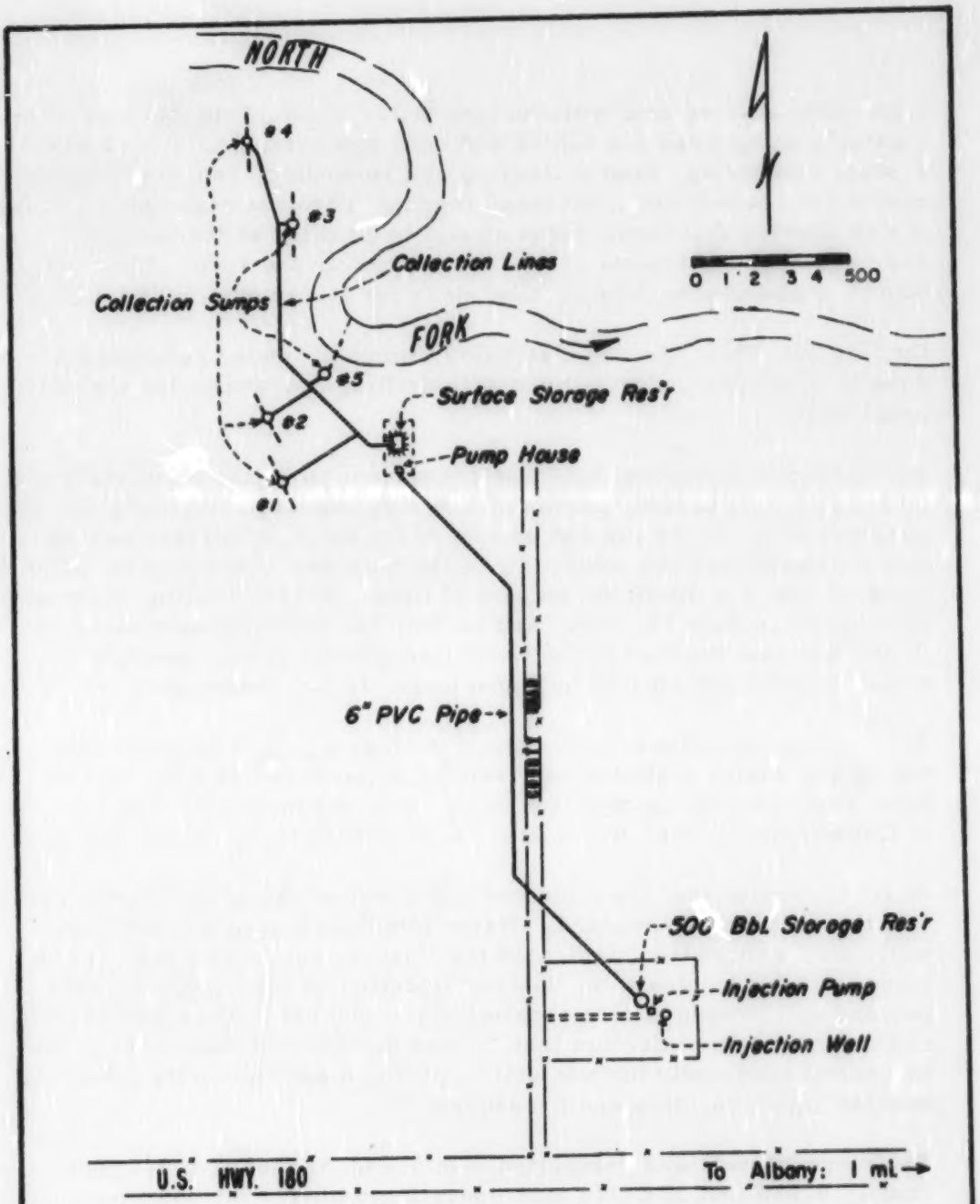

Figure 2. Project layout

tions were entered into with the contractor which eliminated the contractor's obligations for coring and core analysis, drillstem tests, 2-stage cementing, sand fracturing and squeezing, reducing requirements for centralizers, advanced logging, perforations, and acidizing. It was decided that these items should be paid for at the normal rates and requirements typical of well completion in the area. The contract was then awarded to John H. Chalmers for the amount of $64,505.67.

On July 18, 1969, Megargel Drilling Company, under subcontract to John H. Chalmers, commenced with drilling operations for the disposal well.

Re-entry of the existing well was considered to be the most risky and potentially troublesome portion of the disposal well. Drilling out the concrete plugs in the top and bottom of the existing surface casing, and washdown and reconditioning of the hole was accomplished without incident and in a minimum amount of time. Actual drilling of the new hole began on July 20, 1970, and on July 26, the maximum depth of 5,730 feet was reached in the Cambrian granite at the approximate depth that was anticipated by Conselman, Jenke, Associates.

All drilling operations, drillstem test, logging, coring, acidizing, tubing and casing installations, setting of packers and other operations necessary for completion of the well was under the supervision of Conselman, Jenke, Associates, Consultants to the Water District.

Basic formation that the collected brine water was to be disposed in was the Wilberns Greensand. Water injection test of the disposal well, upon completion, indicated that further acidizing needed to be made in order to obtain the desired injection rate of 5,000 barrels per day at a pressure of approximately 1,000 psi. After reacidizing and another water injection test, it was determined that porosity had increased adequately for the well to perform satisfactorily under the desired injection rates and pressures.

The disposal well was completed with 5,742.57 feet of 5-1/2 inch casing; 5,650 feet of 2-7/8 inch operating tubing; hold-down packer, and the cementing of casing pipe from 4,000 feet to the bottom of the hole.

General schematic of the disposal well and injection pump system is shown in Figure 3.

Summary of cost for completion of the disposal well is as follows:

		COST	
1.	Revised Contract, John H. Chalmers		$ 64,605.67
2.	Coring		
	Day Work (33 hrs. @ $41.67)	$ 1,375.00	
	Diamond Coring, Inc. (including bit damage)	1,461.60	
	American Mud Co.	303.57	
	Core Laboratory, Inc.	72.00	
	Reaming bit	233.00	3,445.17
3.	Drillstem Testing		
	Day Work (32 hrs. @ $41.67)	1,333.33	
	American Mud Co.	303.58	
	Halliburton Services	502.00	2,138.91
4.	Initial Completion		
	Enjay Chemical Co. (Corexit)	133.10	
	Halliburton (acid)	212.00	
	Halliburton (test)	134.83	
	Hale Service Co.	598.48	1,078.41
5.	Re-acidization		
	Halliburton	1,544.00	
	McDonald Well Service Co.	537.00	
	Joe T. Smith	241.00	
	Baker Oil Tool	58.18	2,380.18
		TOTAL COST	$ 73,648.34

COLLECTION SUMPS, COLLECTION PIPING, STORAGE AND INJECTION PUMPS

Construction and installation of the collection sumps and piping, water storage, sump pumps, and the deep well injection pumps were performed under a separate contract from that of the contract for

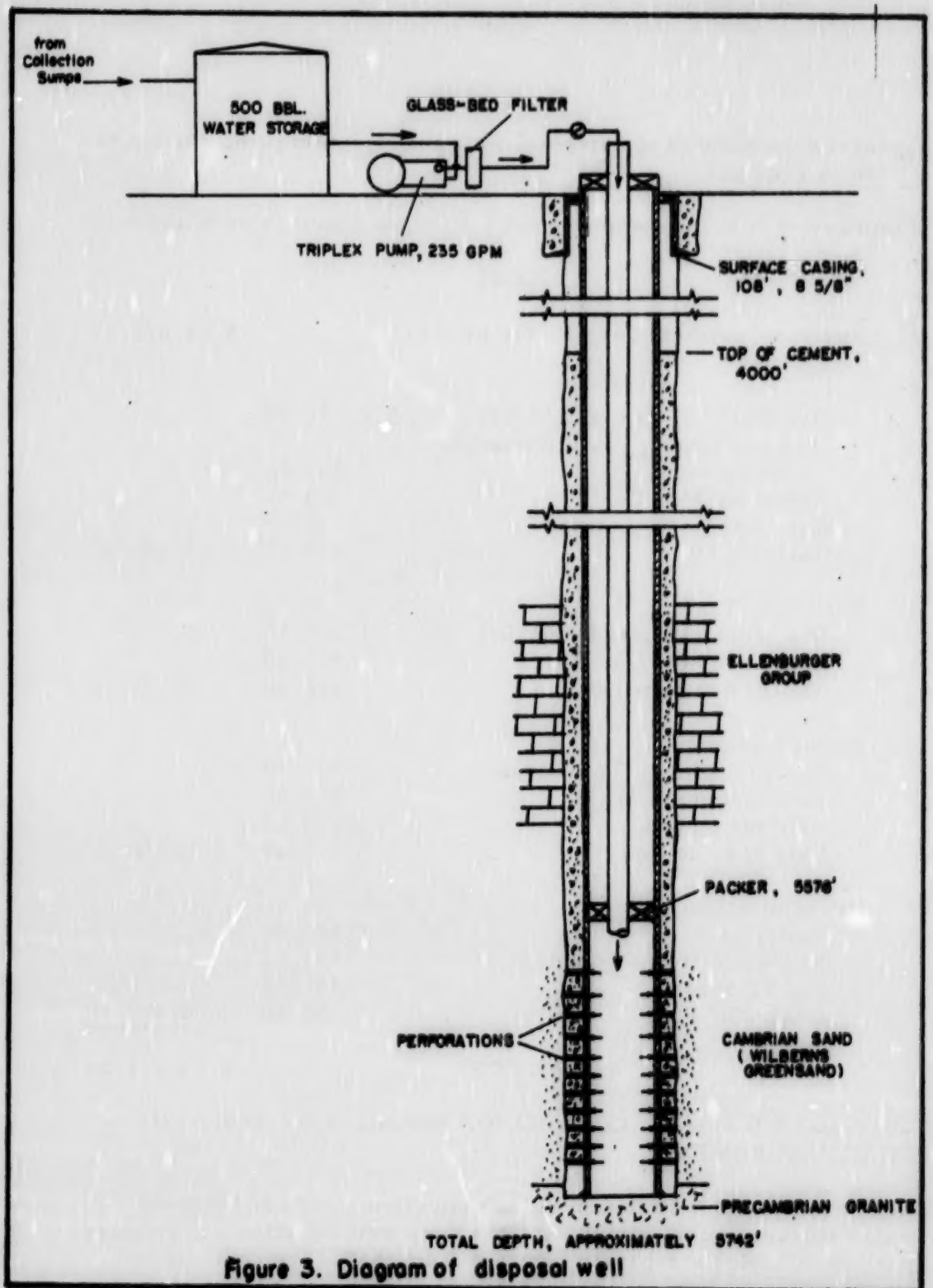

Figure 3. Diagram of disposal well

completion of the disposal well. Bids were received by the District on March 4, 1969, with a low bid for the project submitted in the amount of $143,191.25. This bid was substantially over the project budget; consequently, the scope of the project was negotiated with the low bidder and was reduced by eliminating five upstream collection sumps and sump pumps, and by eliminating the collection system piping that was required by the upstream sumps. Negotiations resulted in reducing the total inplace cost of this phase of the project to $87,106.99.

Features of this phase of the project, as built, included the construction of five collection sumps within the alluvium; 1,400 feet of collection system piping; one lined surface pit for central collection of water from the sumps; a pump station for conveying the collected brine water to a 500-barrel steel storage tank located near the injection well, and the pump station for the injection well.

The collection sumps were constructed within the alluvial material, along the North Fork valley, with the bottom of each sump being excavated to a depth as required to maintain a bottom consisting of an impervious material. The alluvial material in this area is underlain with a shale which has low permeability; consequently, each sump was excavated to the shale bed. Depth of the alluvial material varied from 12 to 18 feet at the location of each sump.

Each collection-sump trench had an 8-inch perforated pipe installed along its bottom, and the pipe was backfilled with a select gravel to a point two feet above the top of the pipe. The remaining trench was then backfilled above the gravel with the porous alluvial material that was excavated from the trench. Length of the perforated pipe in the collection sumps varied from 75 and 125 feet. A pump was installed in each sump for pumpage of the collected water to the central storage pit which was located near the center of the withdrawal area. As shown in Figure 4, Sump No. 5 was constructed adjacent to the creek with perforated pipe laid across the creek bed; then the trench was completely backfilled with select gravel.

The collection system consisted of polyvinyl chloride pipe with the size varying between 1-1/2 inches to 6 inches. Capacities of the sump pumps were approximately 22 gallons per minute. Each sump pump was equipped with a meter to provide pumpage records for project analysis.

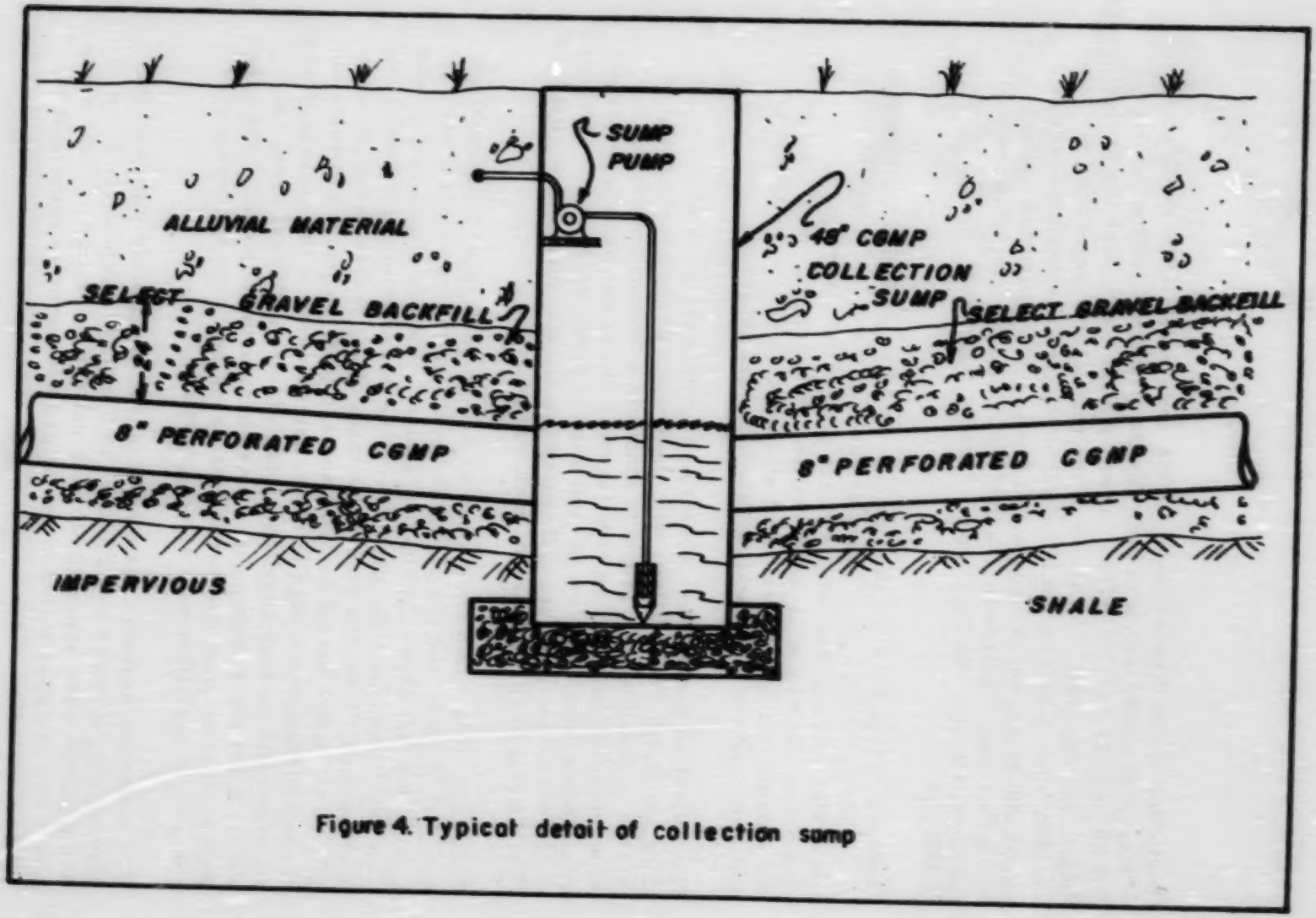

Figure 4. Typical detail of collection sump

Basic features of the water injection pump station consisted of a high-head triplex injection pump with glass-bed filters. The triplex pump was rated at 235 gallons per minute at a head of 1385 feet. The 500-barrel storage tank located near the injection pump served as pump storage and allowed a good operating cycle for the pump.

OBSERVATION WELLS

Numerous observations wells were installed throughout the limits of the project area to serve as data control points and to permit monitoring of chloride concentrations of the underground water. A total of 74 observations wells were drilled at locations as shown in Figure 5.

Each of the observation wells was drilled to a depth sufficient to exceed the depth of alluvial material and into the impervious shale. Depths of the wells ranged from 5 feet to a maximum of 36 feet with most of the wells being less than 20 feet. The observation wells, which were drilled in alluvial deposits with water carrying capabilities, were cased with 5-inch perforated pipe and with gravel placed between the pipe and hole.

Data showing depths of the observation wells, groundwater conditions, and chloride content of groundwater at the time the wells were installed, is shown in Table 1. Observation wells prefixed with "NF" in Table 1 and Figure 5, indicate wells located on the drainage area of North Fork of Hubbard Creek, and wells prefixed by "C" indicate wells located on the drainage area of Cook Creek, a tributary of the North Fork of Hubbard Creek. Data of chloride concentrations measured in the observation wells during the project period is shown in Table 2.

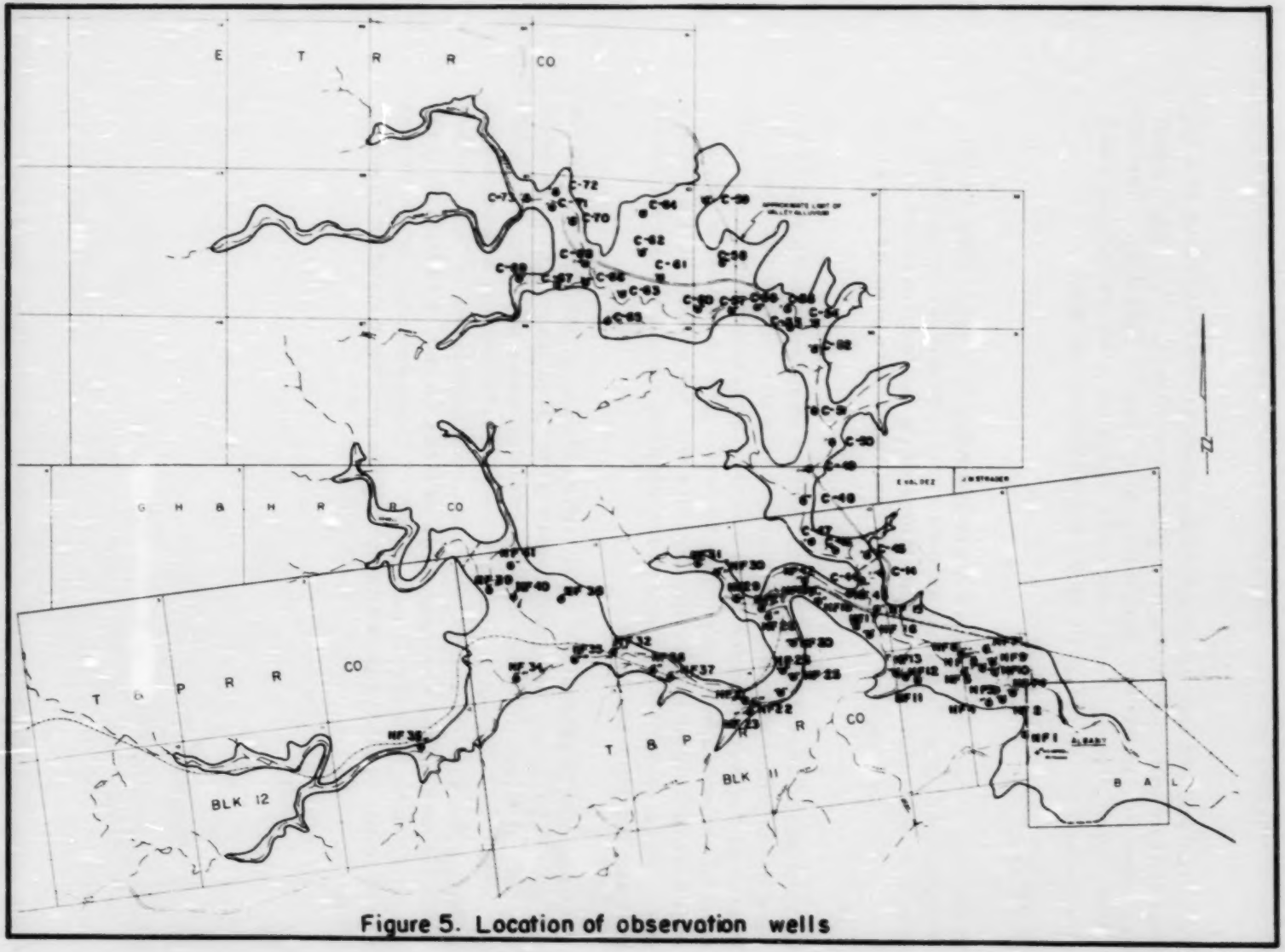

Figure 5. Location of observation wells

Table 1. OBSERVATION WELL DATA

Hole no.	Date drilled	Grd.[a] elev.	Total[b] depth	Base[b] soil	Base[b] alluvium	Total[b] casing	Amount fluid when drilled	Initial chloride, ppm
NF 1	1-16-69	1419.4	13.	3.0	8.5	10.0	Dry	5905
2	"	1411.9	15.	2.5	12.5	16.5	Dry	3045
3	"	1417.1	23.	7.0	19.0	23.5	Moderate	2700
4	"	1421.7	24.	12.0	19.5	23.5	Dry	5400
5	"	1427.8	24.	6.0	17.0	22.5	Dry	
6	"	1427.5	20.	1.0	11.0	15.0	Dry	140
7	"	1432.2	24.	2.5	22.5	24.5	Damp	2905
8	1-17-69	1419.2	16.	5.0	12.0	16.5	Dry	
9	"	1422.1	24.	3.5	21.0	22.5	Abundant	1295
10	"	1417.1	24.	4.0	18.0	20.5	Abundant	1360
11	"	1437.0	24.	2.5	19.5	23.5	Damp	
12	"	1440.4	26.	3.0	23.0	24.5	Abundant	3630
13	"	1441.7	21.	1.5	19.0	19.5	Dry	
C 14	"	1443.7	15.	2.0	9.0	10.5	Dry	
NF 15	"	1439.6	24.	1.0	14.0	15.5	Dry	
16	"	1442.8	26.	3.5	16.0	18.5	Dry	
17	1-21-69	1446.6	24.	4.5	22.0	24.0	Damp	2345
18	"	1456.3	10.	2.5	16.5	None	Dry	
19	"	1457.0	18.	5.0	12.5	16.5	Dry	
20	"	1473.6	15.	5.0	9.5	13.0	Dry	
21	"	1492.7	15.5	3.0	13.6	13.5	Slight	1785
22	1-22-69	1490.1	16.	4.5	10.8	13.0	Dry	
23	"	1493.9	13.	1.0	10.0	12.5	Dry	
24	"	1485.8	16.	3.0	11.5	13.5	Dry	
25	"	1480.9	22.	2.0	17.0	19.5	Moderate	8150
26	"	1485.1	24.	2.5	18.5	20.5	Dry	
27	"	1470.7	5.	1.0	None	None	Dry	
28	"	1474.8	18.	2.0	9.5	12.0	Dry	
29	"	1481.6	10.	2.0	7.5	11.5	Dry	
30	"	1493.3	12.	2.0	9.5	11.5	Dry	
31	"	1498.8	10.	1.5	9.0	11.5	Abundant	1765
32	1-23-69	1521.9	13.	2.5	10.5	14.5	Dry	
33	"	1531.5	18.	1.5	16.0	17.5	Dry	1470
34	"	1551.8	15.5	5.0	15.0	16.5	Damp	
35	"	1594.6	20.	4.5	13.0	14.5	Dry	

Table 1 (continued). OBSERVATION WELL DATA

Hole no.	Date drilled	Grd. elev.[a]	Total depth[b]	Base soil[b]	Base alluvium[b]	Total casing[b]	Amount fluid when drilled	Initial chloride, ppm
NF 36	1-23-69	1510.4	19.	3.0	16.0	16.5	Moderate	1085
37	"	1507.0	17.	1.0	13.0	14.5	Damp	
38	"	1557.5	16.	1.0	12.0	None	Dry	
39	"	1563.7	22.	3.0	18.0	19.5	Damp	
40	"	1553.3	18.	3.0	14.0	15.5	Dry	
41	"	1562.6	10.	0.5	7.0	None	Dry	
42	1-24-69	1456.3	21.	1.5	17.0	22.5	Abundant	2750
43	"	1449.7	18.	0.5	13.0	14.5	Dry	
C 44	"	1453.6	24.	0.5	14.8	17.5	Dry	
45	"	1452.4	15.	2.0	12.0	12.5	Dry	
46	"	1460.1	18.	1.0	15.0	17.5	Abundant	2550
47	"	1462.3	19.	3.5	16.5	19.5	Moderate	3740
48	"	1473.4	19.	1.5	11.0	15.5	Dry	
49	1-27-69	1482.2	16.	4.5	12.0	14.5	Dry	
50	"	1486.8	15.	4.5	12.5	14.5	Dry	
51	"	1496.5	11.	1.0	7.0	8.5	Dry	
52	"	1507.6	15.	1.0	12.5	14.5	Dry	
53	"	1516.9	10.	2.5	8.0	8.5	Damp	
54	"	1511.6	12.	2.0	10.0	10.5	Moderate	2930
55	"	1519.2	15.	2.5	12.0	10.5	Moderate	5675
56	"	1524.4	19.	4.0	18.0	19.5	Damp	
57	"	1529.9	16.	4.0	9.5	12.5	Dry	
58	"	1549.4	21.	3.0	15.0	16.5	Dry	
59	1-28-69	1573.5	16.	3.5	5.5	None	Damp	
60	"	1540.0	19.5	5.5	18.0	19.5	Dry	
61	"	1555.4	20.	7.5	17.0	17.5	Damp	
62	"	1569.4	15.	1.0	10.0	12.5	Dry	
63	"	1558.0	18.	3.5	15.0	17.5	Dry	
64	"	1588.0	20.	5.0	None	None	Dry	
65	"	1573.8	17.	1.5	10.0	12.5	Dry	
66	"	1571.5	21.	2.2	12.0	14.5	Dry	
67	"	1580.0	21.	4.0	12.0	14.5	Trace	
68	1-29-69	1571.9	16.	3.5	12.0	15.5	Dry	
69	"	1602.0	13.	3.0	9.1	10.5	Dry	
70	"	1583.4	19.	2.0	12.5	13.5	Dry	
71	"	1594.5	26.	2.5	25.0	27.5	Abundant	2860
72	"	1597.8	36.	4.0	18.0	27.5	Slight	3470

Table 1 (continued). OBSERVATION WELL DATA

Hole no.	Date drilled	Grd. elev.[a]	Total depth[b]	Base soil[b]	Base alluvium[b]	Total casing[b]	Amount fluid when drilled	Initial chloride, ppm
C 73	1-29-69	1609.1	24.	2.0	22.0	19.5	Moderate	1670
NF 74	"	1415.4	24.	2.0	20.2	21.0	Abundant	2980

[a] Elevation above mean sea level in feet
[b] Depth in feet

Table 2. TYPICAL CHLORIDE CONTENT OF SAMPLES FROM TEST WELLS
(mg/l)

Well No.	3/26/73	1/24/72	12/27/72	5/25/71	6/15/71	8/17/71	9/7/71	11/18/71	12/19/71	2/28/69	11/7/69
NF 1	6,500	6,800	7,450	-	-	-	-	7,400	-	8,575	-
2	2,950	2,425	3,365	2,590	1,200	2,060	2,410	2,500	2,680	3,650	2,750
3	2,520	1,850	2,420	2,255	1,200	1,950	690	1,900	2,510	2,925	2,650
4	5,280	4,100	4,160	3,860	3,455	3,700	3,960	3,700	4,650	4,875	5,150
5	2,700	1,700	2,290	-	-	-	-	-	-	-	-
7	400	740	410	-	450	620	-	680	1,250	2,925	780
9	1,700	1,120	2,010	1,810	700	1,090	550	855	2,250	820	1,650
10	1,860	1,120	2,040	600	1,400	1,220	1,100	690	1,000	1,420	1,710
15	-	-	-	-	2,100	-	-	-	-	2,240	2,800
16	2,500	2,300	2,490	1,470	1,435	1,580	1,540	2,050	2,350	-	2,400
17	-	2,330	2,890	-	1,375	1,240	560	2,240	2,700	2,505	2,450
21	1,780	1,810	1,840	1,700	1,965	1,750	1,870	-	2,150	1,940	1,700
22	3,470	2,360	2,510	3,550	2,325	3,275	3,000	-	3,925	2,155	2,400
23	11,500	6,150	4,760	9,900	5,850	4,050	4,225	-	12,450	14,900	12,250
24	2,670	2,040	1,820	2,550	2,550	2,780	2,325	-	3,100	2,420	2,550
25	3,380	2,880	2,980	2,700	2,180	3,110	3,350	-	3,050	7,575	3,450
26	3,180	2,045	2,800	2,060	1,250	1,830	1,980	-	2,850	3,220	3,000
28	1,230	12,000	10,500	-	11,600	13,250	14,325	-	-	5,525	-
29	690	690	590	1,150	70	840	640	975	1,550	1,075	960
30	1,720	1,580	2,640	-	-	-	-	-	-	1,000	-
31	415	1,020	1,475	-	-	-	-	-	-	1,520	-
32	655	490	380	905	700	880	740	660	1,200	765	1,100
33	1,420	1,750	1,800	1,510	1,110	1,350	1,030	1,130	2,000	1,625	1,950
34	106	100	80	-	90	-	120	75	-	187	435

Table 2 (Continued). TYPICAL CHLORIDE CONTENT OF SAMPLES FROM TEST WELLS

Well No.	3/26/73	1/24/72	12/27/72	5/25/71	6/15/71	8/17/71	9/7/71	11/18/71	12/19/71	2/28/69	11/7/69
NF 36	680	650	620	810	175	330	190	-	1,250	1,180	700
37	9,900	4,500	2,400	4,250	890	3,020	3,500	-	5,600	4,025	5,350
42	1,595	1,850	2,190	-	2,370	2,450	2,080	1,750	2,600	2,980	2,800
43	2,590	3,310	3,880	-	1,230	1,950	2,820	3,250	2,900	3,400	2,375
C 45	210	-	170	250	330	290	310	-	305	278	220
46	2,350	-	2,900	2,350	1,340	1,980	1,250	-	2,800	2,730	2,300
47	2,465	-	2,900	1,040	750	480	1,865	-	3,500	3,870	2,900
48	5,825	2,950	5,100	3,680	3,550	1,[illegible]	4,050	-	4,650	5,325	4,900
50	2,875	2,290	3,750	2,320	1,870	2,175	2,200	-	2,750	3,560	2,900
53	9,075	5,360	7,950	-	2,185	-	-	-	6,500	6,375	5,700
54	1,070	4,300	4,460	4,380	4,360	7,550	5,850	-	3,800	3,575	3,600
55	810	4,650	4,120	5,500	555	4,700	4,425	-	5,150	6,300	5,350
56	7,000	5,650	5,800	3,560	3,960	3,900	4,500	-	3,100	3,250	3,450
57	2,480	1,925	1,840	2,000	2,250	2,050	1,390	-	1,800	3,500	1,850
60	3,580	3,000	1,965	4,500	4,200	4,600	4,600	-	5,000	5,750	1,550
63	4,700	7,800	7,950	4,200	1,780	3,850	[illegible]50	-	5,000	6,000	4,550
67	7,550	15,650	5,650	6,600	1,225	750	[illegible]50	-	5,950	8,700	
68	-	3,600	-	5,300	3,975	3,950	4,250	-	6,500	6,625	6,850
70	5,680	3,000	1,600	3,600	3,500	3,750	3,100	-	4,700		4,200
71	2,895	2,450	2,270	2,070	1,710	2,050	1,950	-	2,500	3,425	2,100
72	4,030	2,500	3,860	3,050	2,150	2,300	1,930	-	3,100	3,675	2,450
73	-	1,300	1,190	1,200	375	1,070	470	-	1,600	1,810	1,450
NF 74	-	2,000	1,750	2,380	2,250	1,950	1,760	1,750	2,650	3,060	2,650

SECTION VII

MONITORING AND TESTING

Upon completion of construction and installation of facilities for the project, a comprehensive monitoring and testing program was established to determine the effect of the project operation on groundwater contamination in the project area as well as water quality downstream from the project.

Laboratory facilities in the offices of the Water District and offices of Conselman, Jenke, Associates, Consultants to the District, were utilized to determine chloride content of samples taken from the observation wells, collection sumps, storage facilities, and North Fork of Hubbard Creek within the project area. Analysis of downstream flows and water quality was obtained by use of permanent monitoring stations that were installed and maintained by the United States Geological Survey.

U. S. Geological Survey stations utilized for monitoring quantity and quality of flows downstream from the project site were Stations 8-0861.5, North Fork near Albany; Station 8-0862.12, Hubbard Creek below Albany; Station 8-0861.0, Hubbard Creek near Albany; and Station 8-0864.0, Hubbard Creek Reservoir. Locations of the U. S. G. S. monitoring stations are shown in Figure 6.

Flows measured at Station 8-0861.0 are not affected by flows from the project area. Quantity and quality of flows measured at this station were reviewed for comparison with flows from the project area as reflected in flow records from Station 8-0861.5.

The procedure utilized by the Water District in monitoring and testing water quality, was to obtain samples from the observation wells and collection sumps on a routine basis. These samples were analyzed to determine the rate of decontamination caused by dewatering and subsequent refill of the alluvium from fresh water runoff.

As mentioned previously, each of the sump pumps that was installed in a collection sump was equipped with a flow meter. Volume of water pumped from the alluvium was recorded on a daily basis. Amount of chlorides, expressed in tons, could therefore be calculated

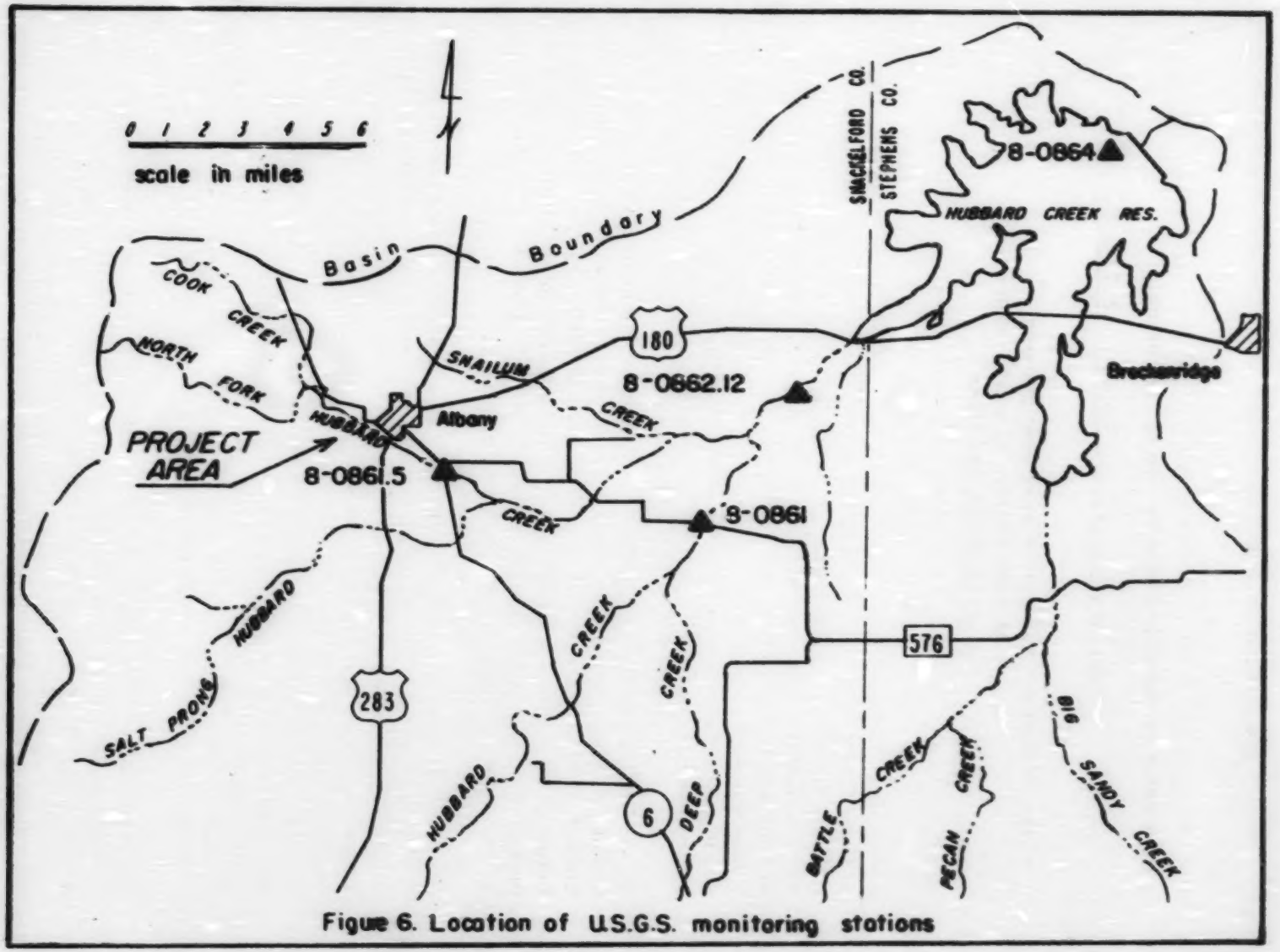

Figure 6. Location of U.S.G.S. monitoring stations

on a daily or monthly basis by use of the formula:

$$\text{Tons of Chlorides} = \frac{\text{Volume} \times 2.72 \times C.}{2,000}$$

where Volume = number of acre-feet pumped
C. = chloride content of water, expressed in milligrams per liter.

SECTION VIII

PROJECT DISCUSSION

Construction of the project facilities was completed during the last part of March 1970, with operations of withdrawal and pumpage from the collection sumps beginning on April 1, 1970.

During the first few months of operation, four of the collection sumps produced water at the total rate of about 101,000 gallons per day. During the first four months of operation, Sumps No. 1, 2, 3, and 4 consistently produced a supply of water for injection to the disposal well; however, during July 1970, the daily withdrawal rates from Sumps 2, 3, and 4 began to decline, and production dropped to zero at these three sumps before the end of the month.

Collection Sump No. 5, which was constructed across the creek bed of North Fork, was expected to be the major collector of alluvium water flows, since it would intercept low flows in the North Fork, as well as local underground water in the alluvium. During the first two months of operation, Sump No. 5 did not yield any water primarily due to pump malfunction; however, upon correction of these problems, this sump pumped 1.03 million gallons of water during the last few days of May and during the month of June. After June 1970, this sump produced only a small amount of water for the duration of the project as is shown in the pumpage records, Table 3. Primary reason that this sump did not yield water is suspected to have been due to clogging of the collection trench by silt and clay.

Records of water withdrawal and pumpage from each of the collection sumps on a monthly basis is shown in Table 3. As evident upon review of Table 3, Sumps No. 1 and 3 were the only sumps that produced water on a consistent basis as well as being capable of removing a significant amount of water from the alluvial deposits. Sump No. 4 produced water on a rather sporadic basis, indicating that the alluvial material that it was draining was local in nature and did not intersect the alluvial deposits drained by Sumps No. 1 and 3. Sump No. 2 produced water for about four months before production declined to zero and did not yield water for the duration of the project.

Table 3. RECORD OF PUMPAGE FROM COLLECTION SUMPS
(million gallons)
April 1970 to March 1973

Month	Years	Sump #1	Sump #2	Sump #3	Sump #4	Sump #5
Jan.	1971	0	0	0	0	0
	1972	1.489	0	1.9578	0	0
	1973	2.121	0	1.9133	0.5047	0
	Total	3.610	0	3.8711	0.5047	0
Feb.	1971	0	0	0	0	0
	1972	1.3053	0	1.442	0	0
	1973	1.9693	0	1.7482	0.9198	0
	Total	3.2746	0	3.1902	0.9198	0
Mar.	1971	0	0	0	0	0
	1972	1.237	0	1.2457	0	0
	1973	0	0	0	0	0
	Total	1.237	0	1.2457	0	0
April	1970	1.3417	0.6494	0.8058	0.7659	0
	1971	0	0	0	0	0
	1972	0.9177	0	1.0172	0	0
	Total	2.2594	0.6494	1.8230	0.7659	0
May	1970	0.2853	0.3497	0.2373	0.1434	0.1743
	1971	0	0	0	0	0
	1972	1.1722	0	1.2638	0	0
	Total	1.4575	0.3497	1.5011	0.1434	0.1743
June	1970	1.3272	1.1672	1.109	1.0125	0.858
	1971	0.1694	0	0.8059	0	0.032
	1972	1.2033	0	1.5164	0.2339	0
	Total	2.6999	1.1672	3.4313	1.2464	0.890

Table 3 (continued). RECORD OF PUMPAGE FROM COLLECTION SUMPS
(million gallons)

Month	Years	Sump #1	Sump #2	Sump #3	Sump #4	Sump #5
July	1970	1.7083	0.325	1.7864	0.1234	0.0347
	1971	0.3298	0	0.1624	0	0
	1972	0.7488	0	0.6277	0	0
	Total	2.7869	0.325	2.5765	0.1234	0.0347
August	1970	0.018	0	0.009	0	0
	1971	0.3033	0	0.0775	0.115	0.0256
	1972	0.5291	0	0.7096	0	0
	Total	0.8504	0	0.7961	0.115	0.0256
Sept.	1970	0.3196	0	0.1554	0	0
	1971	0.3438	0	1.1798	0.1797	0
	1972	0.5843	0	0.8998	0	0
	Total	1.2477	0	2.235	0.1797	0
Oct.	1970	0.1637	0	0.0452	0	0
	1971	0.6242	0	1.8226	0.0706	0
	1972	0.8524	0	1.4321	0	0
	Total	1.6403	0	3.2999	0.0706	0
Nov.	1970	0.0317	0	0	0	0
	1971	0.9229	0	1.5973	0	0
	1972	1.914	0	1.1041	1.6262	0
	Total	2.8686	0	2.7014	1.6263	0
Dec.	1970	0	0	0	0	0
	1971	0.9152	0	1.8311	0.0924	0
	1972	2.0738	0	1.8358	0.8592	0
	Total	2.989	0	3.6669	0.9516	0
PROJECT TOTAL		26.9213	2.4913	30.3382	6.6468	1.1246

PROJECT TOTAL OF ALL COLLECTION SUMPS: 67.5222 MG

Testing of water samples to determine chloride concentrations in the alluvial water at each sump was performed by the Water District for the duration of the project. The weighted average chloride content, by month, is shown in Figure 7. Chloride content of water samples from Sumps 2 and 5 are not depicted in Figure 7 because these two sumps were dry, except for the first few months of operation.

During the period from January 1970 to July 1971, the alluvial material contributing to each sump was almost completely dewatered as indicated in the pumpage records of Table 3 and in Figure 7. Dewatering of the alluvial deposits was helped considerably because of the extremely dry weather that was experienced in the project area from October 1970 to May 1971. The small amount of rainfall that fell on the North Fork watershed during this period did not produce any runoff and occurred during the month in such small amounts that the topsoil of the alluvial material was hardly more than moistened. Records of annual rainfall at Albany, Texas, located adjacent to the project site is shown in Table 4.

These extremely dry conditions, and dewatering of each collection sump, offered the ideal condition to aid in the demonstration for determining the rate of decontamination of the alluvium by dewatering and subsequent recharge.

Rainfall within the project area began to increase during May 1971, and a period of very wet weather conditions continued until January 1972. Wet weather conditions occurred again from April 1972 to January 1973. Intensity of rainfall in this period was moderate, allowing the alluvium to be recharged at almost a continuous rate for the last 20 months of the project period. As shown in Figure 7, chloride content of the alluvial waters withdrawn from the sumps made a pronounced decrease upon recharge of the alluvial aquifer. In June 1972, Sump No. 1 experienced a chloride reduction of 21 percent, and Sump No. 3 had a reduction of 38 percent as compared to the previous chloride content reported in December of 1971.

Correlation of the monthly chloride content of water from the alluvium with monthly rainfall indicates that as the monthly rainfall increases, the chloride concentration will decrease, but will depend upon the water-holding capacity of the alluvial deposit contributing to the source of pressure or volume relief. For example, during the

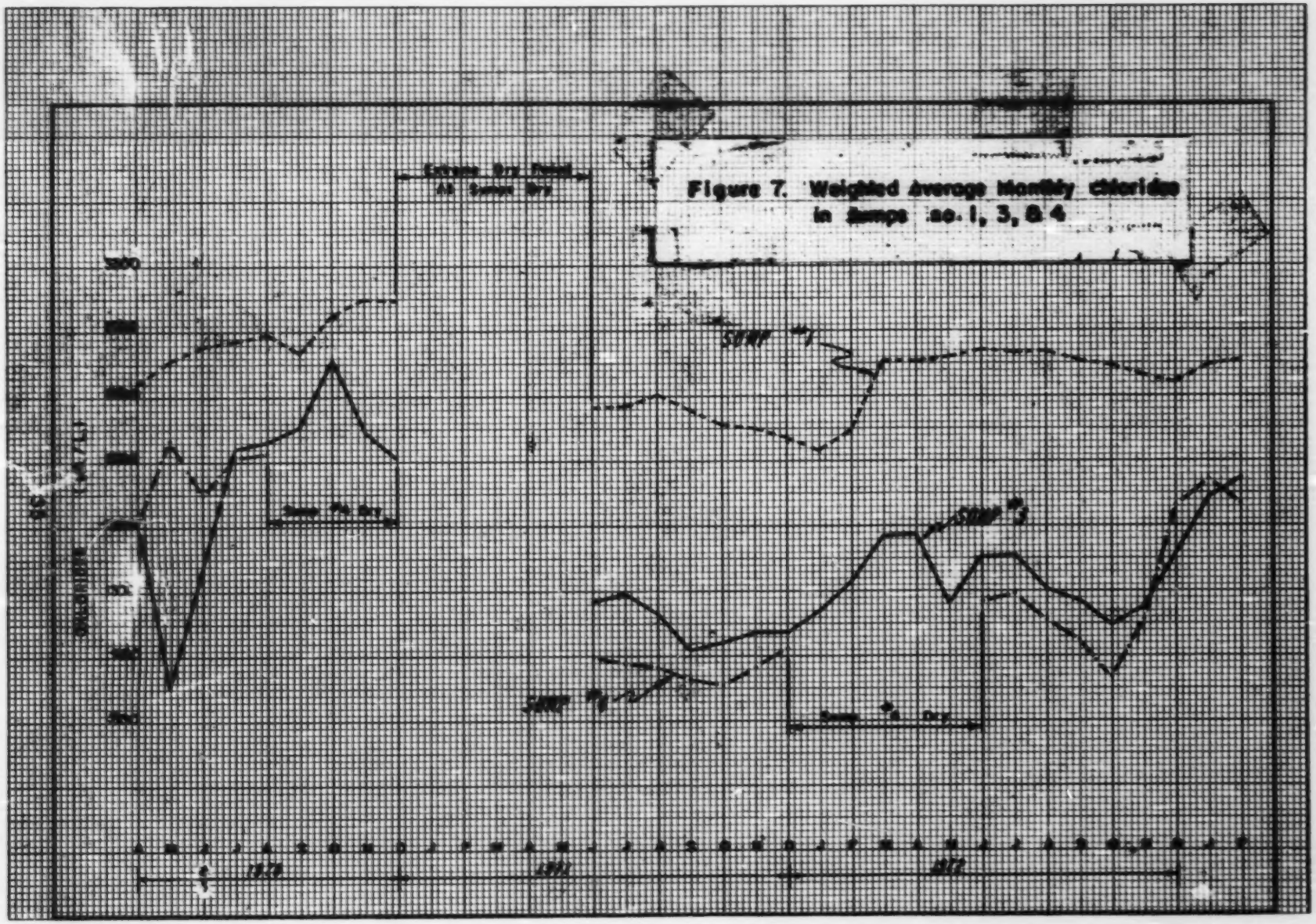

Figure 7. Weighted Average Monthly Chlorides in Sumps no. 1, 3, & 4

Table 4. MONTHLY AND YEARLY PERCIPITATION FOR THE PROJECT AREA,
From U. S. Weather Bureau Records At Albany, Texas

Water year	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	August	Sept.	Total
1963	1.44	1.06	1.19	.04	.31	.08	3.43	4.78	2.9	.98	1.67	1.74	19.62
1964	.91	6.09	.60	2.58	2.77	1.51	1.47	3.71	1.5	.05	3.29	3.69	28.17
1965	.87	3.83	.32	1.75	1.66	.48	4.53	7.99	2.41	.22	1.97	3.82	29.85
1966	3.19	.22	1.56	1.76	.79	1.49	6.98	2.73	1.5	.41	6.34	4.87	31.84
1967	1.24	.38	.09	.00	.29	.85	1.52	5.19	2.54	1.21	1.43	6.72	21.46
1968	2.41	2.15	2.55	8.13	2.87	2.16	2.43	2.31	3.26	3.68	.32	.31	32.58
1969	0.24	3.65	.66	.68	2.87	3.67	2.36	7.30	4.56	T	1.38	4.68	32.05
1970	2.44	.91	3.49	0	2.01	1.68	6.02	1.94	.10	T	1.93	4.17	24.69
1971	1.62	.16	.22	.05	.80	.09	1.01	4.93	1.32	2.16	4.79	4.43	21.58
1972	2.73	.2	2.37	.00	.25	.25	3.15	3.99	1.51	1.56	4.35	4.40	24.76
1973	6.87	.80	.08	2.98									

months of June and July 1972, rainfall for the month was 1.51 and 1.56 inches, respectively, and the chloride concentration of Sump No. 3 remained fairly constant at about 1650 mg/l. Monthly rainfall then increased during August, September, and October to a maximum of 6.87 inches then decreased to less than an inch in November. Chloride concentrations in Sumps No. 3 and 4 showed a marked decrease during the wetter months and a pronounced increase as the rainfall decreased.

Chloride content in Sump No. 1 did not show the pronounced decrease with the increase of rainfall as experienced in Sumps 3 and 4, giving reason to believe that the capacity of the alluvial deposit being drained is larger than that drained by Sump No. 3. Consequently, more time is given to the leaching of chlorides from the alluvium as the water travels through the alluvial deposits.

The higher value of chloride concentrations from Sump No. 1, as compared to Sump No. 3, also gives reason to believe that continuity of the alluvial deposits in the project area does not exist and that small pockets of alluvial material have been deposited throughout the area containing varying water-holding capacities and degrees of salt water contamination. This condition is also indicated in the records of chlorides for each of the observation wells as shown in Table 3. Figure 7 indicates that the chloride concentration of water withdrawn from the sumps was virtually the same at initiation and completion of the project.

Results of the dewatering of the alluvium within the project area, and subsequent recharging that has taken place during the last 20 months of wet-weather conditions, indicate that decontamination of the alluvium from residual salts will take place at a very slow pace over a period of many years. It is not likely that the chloride concentrations of the alluvium water will be reduced to 50 mg/l in the foreseeable future.

A summary by months showing the weighted average chlorides from all the collection sumps, amount of water injected into the disposal well, tons of chlorides injected, and monthly cost for operations during the project period is shown in Table 5. It is noted that monthly operating costs, as shown in the table, include only the cost of the project operator, facility maintenance, and power for pump operation. Capital cost of the facilities and supervision by the Water District personnel are not included.

Table 5. SUMMARY OF PROJECT DATA

Month	Weighted average chloride ppm	Ac. Ft. water ejected	Tons chloride ejected	Monthly operating cost	Cost per barrel water ejected	Cost per ac. ft. water ejected	Cost per ton chloride ejected
Apr. 70	1990	11.96	32.4	$ 844.23	$0.009	$ 70.59	$ 23.00
May	1780	3.79	9.2	3,802.08	.137	1,003.19	431.00
June	2145	18.79	54.9	1,161.05	.008	61.79	21.15
July	2490	12.44	42.1	904.85	.009	72.74	21.49
Aug.	2535	3.92	13.5	835.96	.0274	213.26	61.92
Sept.	2620	1.46	5.2	862.57	.0763	590.80	165.99
Oct.	2985	0.64	2.6	400.00	.0844	625.00	153.85
Nov.	3110	0.10	.4	533.00	.7059	5,330.00	1,332.50
Dec.	0	0	0	584.85	0	0	0
Jan. 71	0	0	0	705.45	0	0	0
Feb.	0	0	0	1,400.00	0	0	0
Mar.	0	0	0	400.00	0	0	0
Apr.	0	0	0	533.00	0	0	0
May	0	0	0	533.00	0	0	0
June	1560	3.09	6.6	573.03	.0239	185.45	86.82
July	2045	1.51	4.2	575.51	.0491	381.13	137.03
Aug.	2150	1.6	4.68	705.02	.0568	440.64	150.65
Sept.	1298	5.22	9.24	571.16	.0127	109.33	61.84
Oct.	1298	7.72	13.64	481.92[a]	.0080[a]	62.42[a]	35.33[a]
Nov.	1519	7.73	15.98	627.48	.0105	81.17	39.27
Dec.	1486	8.71	17.02	925.75[b]	.0137[b]	106.29[b]	54.39[b]
Jan. 72	1609	10.58	23.17	785.85	.0096	74.28	33.92
Feb.	1809	8.43	20.76	795.55	.0122	94.37	38.32
Mar.	1953	7.61	22.41	684.95	.0116	90.01	30.56
Apr.	2166	5.94	17.44	666.23	.0145	112.16	38.20
May	1971	7.47	19.99	703.79	.0121	94.19	35.22
June	1992	9.06	24.49	904.50	.0128	99.84	36.93
July	2181	4.22	12.49	645.37	.0197	152.86	51.67
Aug.	1927	3.80	9.94	629.36	.0213	165.62	63.34
Sept.	1818	4.55	11.23	590.93	.0167	129.82	52.63
Oct.	1635	7.01	15.54	668.56	.0122	95.41	43.01
Nov.	1671	14.25	32.31	861.11	.0077	60.45	26.65
Dec.	2037	14.63	40.45	1,000.92	.0088	68.42	24.74
Jan. 73	2274	13.92	42.97	964.95	.0089	69.30	22.45
Feb.	2267	14.23	43.78	1,683.62	.0152	118.35	38.46
Total		214.38	568.63	$30,070.45			
Average	2011	6.13	16.25	$ 859.16	.0181	140.27	52.88

[a] No electric power charge included in this figure.
[b] Electric power cost for two months included in this figure.

The project summary indicates that 568.63 tons of salt have been withdrawn from the alluvium that contributed contaminated water to the five sumps during the operation of the demonstration project. It is obvious that a portion of this salt load would have been discharged into North Fork and eventually deposited into Hubbard Creek Reservoir. How much of this salt load would have reached the reservoir is a question that remains unanswered. The effect that this chloride reduction could have conceivably made on the quality of water in Hubbard Creek Reservoir can be generalized by review of the annual chloride and dissolved solids loads that have been recorded at the monitoring stations downstream from the project site. Tables 6, 7, and 8 contain data on the annual flows and chloride loadings measured at monitoring stations downstream from the project site. Data shown is compiled from published and unpublished records made available to the Water District by the United States Geological Survey, and is subject to revision. Table 6 shows the historic record of chloride concentrations in the North Fork of Hubbard Creek from 1963 to 1972. This table indicates that the total chloride loading measured at this monitoring station is extremely variable from year to year, and is dependent on the amount of water discharged and the chloride concentration of streamflow. Comparison of average daily discharge and chloride loadings measured at this station for the years of 1964 and 1971, with 1963 and 1972, indicates that reduction of yearly chloride loadings brought about by the demonstration project was substantial.

It should be pointed out, however, that in 1964, the Railroad Commission of Texas issued the "No Pit" regulation, which placed a prohibition on disposal of oil-field brine into unlined earthen pits; and that in the period from 1964 to 1966, all of the then existing surface storage pits were abandoned and covered over. Also during this period of time, many abandoned oil wells that had been improperly plugged were reworked and replugged, and improvements in secondary oil recovery operations and brine disposal operations were experienced within the watershed of North Fork and Cook Creeks.

Correlating flow and chloride loading data measured at Station 8-0861.5, North Fork near Albany, Table 6, with Station 8-0862.12, Hubbard Creek below Albany, Table 7, indicates that flows from North Fork contributed 6.6% of the flow measured at Station 8-0862.12 during the period 1969 thru 1972, and contributed 8.1% of the chloride loading at this station. This represents a considerable reduction in the

Table 6. ANNUAL CHLORIDE & DISSOLVED SOLIDS LOADINGS[a]
U. S. G. S. Station -8-0861.50
North Fork Hubbard Creek Near Albany

Year[b]	Avg. daily discharge, cfs	Chlorides		Dissolved solids		Discharge, ac. ft.
		mg/l[c]	tons	mg/l[c]	tons	
1963	0.7	1,860	1,170	3,170	1,970	507
1964	1.4	1,370	1,830	2,290	3,170	1,013
1965	5.0	649	3,200	1,200	5,900	3,618
1966	4.9	710	3,430	1,290	6,230	3,546
1967	0.87	1,270	1,090	1,270	1,890	629
1968	12.7	673	8,440	-	-	9,191
1969	8.31	534	4,371	2,851	8,281	6,011
1970	1.99	701	1,374	2,772	2,470	1,440
1971	1.3	505	645	2,129	1,263	938
1972	0.51	780	390	1,470	730	369

[a] From published and unpublished records of United States Geological Survey.
[b] Water Year - October to September
[c] Weighted Average

Table 7. ANNUAL CHLORIDE & DISSOLVED SOLIDS LOADINGS[a]
U. S. G. S. Station -8-0862.12
Hubbard Creek Below Albany

Year[b]	Avg. daily discharge cfs	Chlorides		Dissolved solids		Discharge ac. ft.
		mg/l[c]	tons	mg/l[c]	tons	
1967	15.6	116	2,090			11,290
1968	182.1	165	29,700			131,760
1969	91.2	131	11,800	370	33,700	66,000
1970	63.34	210	13,126	542	33,559	45,838
1971	23.44	155	3,571	408	9,347	16,965
1972	6.15	410	2,500	803	5,040	4,451

[a] From published and unpublished records of United States Geological Survey.
[b] Water Year - October to September.
[c] Weighted Average.

Table 8. ANNUAL CHLORIDE & DISSOLVED SOLIDS LOADINGS[a]
U. S. G. S. Station -8-0861.00
Hubbard Creek Near Albany

Year[b]	Avg. daily discharge cfs	Chlorides		Dissolved solids		Discharge ac. ft.
		mg/l[c]	tons	mg/l[c]	tons	
1969	63.36	129	8,077	391	24,223	45,853
1970	39.92	197	7,750	564	22,190	28,890
1971	19.01	98	1,831	322	5,981	13,757
1972	5.98	250	1,460	570	3,380	4,328

[a] From published and unpublished records of United States Geological Survey.
[b] Water Year - October to September.
[c] Weighted Averages.

chloride loading contributed by North Fork when compared to the 38% chloride loading from the North Fork area for the period 1962 to 1965. Percent of flow contributed from the North Fork was fairly consistent during the two periods, with the percentage being 6.6 from 1969 thru 1972, and 9% from 1962 to 1965. Review of data shown in Table 8, Station 8-0861-0, Hubbard Creek near Albany, reveals varied data on flows past this station. It does not appear that any significant improvements or changes in water quality measured at this station occurred during the project period. Problems of salt water pollution on the drainage area of this station were not as serious as those on the North Fork-Cook Creek drainage area, therefore, it is believed that efforts to clean up smaller areas of pollution brought about by the "No Pit" regulation did not affect water quality as much as the larger concentrated areas of pollution such as were found on the North Fork watershed.

The relatively small amount (569 tons) of chlorides injected into the disposal well during this project, indicates that the major improvement of water quality has occurred through clean up of highly polluted surface areas rather than removal of contamination from the alluvium.

Effect of the chloride removal from the alluvium during the course of the project had on the water quality of Hubbard Creek Reservoir could theoretically be determined by using the relationship of inflow into the lake, chloride loading, and evaporation rates for a selected period of time. Effect can more simply be shown by use of a hypothetical case; assuming the lake at capacity, chloride load into the lake of 569 tons, and no inflow. Comparison of chloride concentrations in the lake with the 569 tons chloride loading that was removed during the project and the chloride residual that would be caused only by evaporation can demonstrate and approach the actual conditions of quality of water in the reservoir.

This hypothetical condition was almost simulated during the extremely dry period of October 1970 to April 1971, when practically no inflow into Hubbard Creek Reservoir was recorded. Assumption of chloride residual of the lake waters will be selected as 161 mg/l, as this was the actual condition in the year 1969 when the lake was at capacity and was just prior to the project period. Evaporation rate will be assumed to be 2.63 feet, which was the rate for the period of October to April for year 1964 to 1965, as presented in the Texas

Water Development Board, Report 64, for quadrangle E-8.

HYPOTHETICAL CASE 1: RESERVOIR AT CAPACITY

Calculations for determining the concentrations of chlorides expected in the reservoir; considering no inflow, a chloride loading of 569 tons and the effects of evaporation for the period of October 1970 to April 1971, are as follows:

$$VR = SA \times ER \quad (1)$$

where VR = reduction of lake volume caused by evaporation, acre-feet
SA = surface area of reservoir, acres
ER = evaporation rate, feet

$$VR = 15,000 \times 2.63$$
$$VR = 39,450$$

$$V = A - VR \quad (2)$$

where V = volume of reservoir after evaporation, acre-feet
A = volume of lake when full, acre-feet
VR = reduction of volume caused by evaporation

$$V = 317,800 - 39,450$$
$$V = 278,350$$

$$TCR = \frac{C \times VF \times 2.72}{2000} + 569 \quad (3)$$

where TCR = chlorides in reservoir after evaporation, including chlorides disposed of during project, tons
C = chloride content of reservoir in October 1970, mg/l
VF = volume of full reservoir, acre-feet

$$TCR = \frac{161 \times 317,800 \times 2.72}{2000} + 569$$

$$TCR = 70,154$$

$$CC = \frac{TCR \times 2000}{V \times 2.72} \quad (4)$$

where CC = concentration of chlorides expected in April 1971, mg/l
TCR = chlorides in reservoir after evaporation, including chlorides disposed of during project, tons
V = volume of reservoir after evaporation, acre-feet

$$CC = \frac{70,154 \times 2000}{278,350 \times 2.72}$$

$$CC = 185.3$$

$$CI = \frac{CC - C}{C} \times 100 \quad (5)$$

where CI = percent of chloride increase from October 1970 to April 1971
CC = calculated chloride concentration for April 1971, mg/l
C = chloride content of reservoir in October 1970, mg/l

$$CI = \frac{185.3 - 161}{161} \times 100$$

$$CI = 15.1$$

HYPOTHETICAL CASE 2: RESERVOIR AT CAPACITY

Calculations for determining the concentrations of chlorides expected in the reservoir considering no inflow and the effects of evaporation for the period of October 1970 to April 1971 are made excluding the chlorides removed during the project for comparison purposes. Calculations for the hypothetical case are as follows:

$$TCR = \frac{C \times VF \times 2.72}{2000} \quad (6)$$

Where TCR = chlorides in reservoir after evaporation, tons
C = chloride content of reservoir in October 1970, mg/l
VF = volume of full reservoir, acre-feet

$$TCR = \frac{161 \times 317,800 \times 2.72}{2000}$$

$$TCR = 69,585$$

$$CC = \frac{TCR \times 2000}{V \times 2.72} \quad (7)$$

where CC = concentration of chlorides expected in April 1971, mg/l
TCR = chlorides in reservoir after evaporation, tons
V = volume of reservoir after evaporation, acre-feet

$$CC = \frac{69,585 \times 2000}{278,350 \times 2.72}$$

$$CC = 183.8$$

$$CI = \frac{CC - C}{C} \times 100 \quad (8)$$

where CI = percent of chloride increase from October 1970 to April 1971
CC = calculated chloride concentration for April 1971, mg/l
C = chloride content of reservoir in October 1970, mg/l

$$CI = \frac{183.8 - 161}{161} \times 100$$

$$CI = 14.2$$

These hypothetical conditions demonstrate that loading of the reservoir with the chlorides removed during the project period would theoretically increase the chloride concentration in the reservoir by

0.9 percent, or 1.5 mg/l, over and above the increase of chlorides that would be contributed by surface evaporation alone. Surface evaporation would, therefore, be considered as the major factor for increased chloride residuals in the reservoir.

Table 9. CHLORIDE CONTENT OF HUBBARD CREEK RESERVOIR
U.S.G.S. Station 8-0864.0

Date	Chlorides, mg/l
July 15, 1969	161
July 15, 1970	198
June 15, 1971	240
September 12, 1972	284
March 23, 1973	284

Table 9 shows the actual concentrations of chlorides in the reservoir as determined from data available from Station 8-0864-0, located in the reservoir. It is interesting to note that chloride concentrations in the reservoir, as shown in this table on July 15, 1969, and July 15, 1970, increased very closely to that as calculated in the hypothetical condition.

The insignificant effect that the alluvium waters appear to have on the chloride content of the reservoir is demonstrated further by reviewing the relationship between chloride content and streamflows. Figure 8, shows this general relationship at Station 8-862.12, Hubbard Creek below Albany. This figure shows that the relationship between flow and chloride concentration was very eratic. This is presumed to be caused by the many variable factors of the watershed itself as well as the unpredictable amounts of rainfall in the West Texas area. Review of the daily records of flow and chloride concentrations for the period 1969 to 1972 will reveal that the difference between chloride concentration of low flows versus high flows appears to be smaller for the year 1972 versus 1969. It also indicates that antecedent conditions result in a large variation of flow versus chloride content. For example, most of the low chloride concentration that is experienced with low flows, as indicated in Figure 8, are pre-

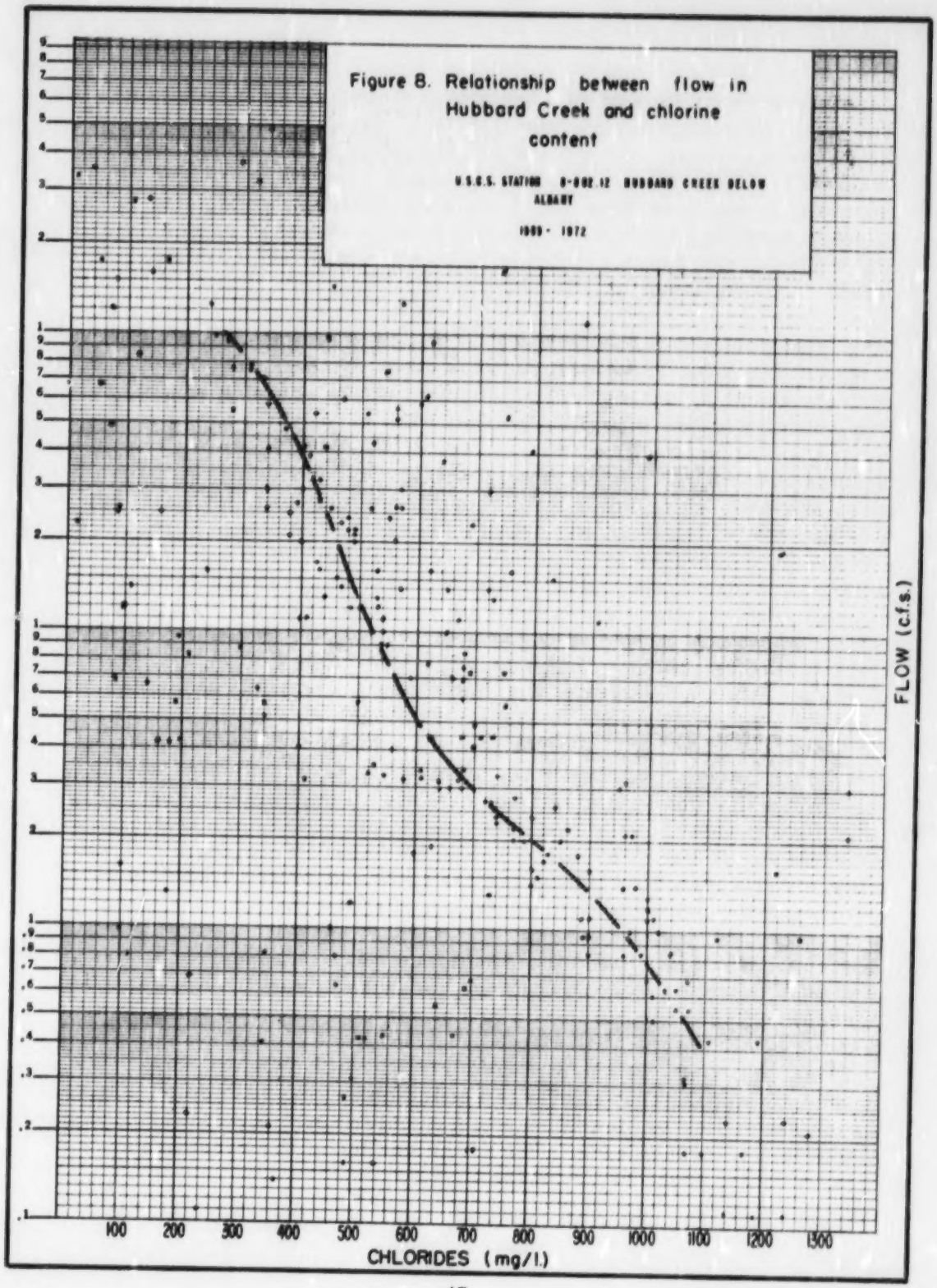

Figure 8. Relationship between flow in Hubbard Creek and chlorine content

U.S.G.S. STATION 8-082.12 HUBBARD CREEK BELOW ALBANY

1969 - 1972

ceded by several days of relatively high flows caused by high intensity rainfall. Also according to the U. S. G. S. data, the larger flows, such as 50 cfs and above, are generally associated with chloride concentrations of 120 to 340 mg/l. This appears to be rather unique, since normally it would be expected to receive relatively small concentrations at such large flows. Evaporation of brine water on and near the surface, and years of surface saturation with brine water, contributes to this situation.

One important observation shown on Figure 8 is that chloride concentrations decrease with an increase in flow, although very seldom does it decrease to the 50 mg/l recommended by the chloride routing study for obtaining a lake chloride concentration of under 250 mg/l.

Efforts of work performed in conjunction with this demonstration project, and data collected on water quality and quantity, indicate that low flows of North Fork of Hubbard Creek, and Hubbard Creek, still contain chloride contents that vary from 450 to 1300 mg/l. Chloride content of those flows under 10 cfs decrease to less than 450 mg/l at times; however, this decrease usually occurs after the initial wash-off of the watershed that is associated with higher flows.

The high chloride content of low flows contribute to the chloride loading of the reservoir; however, the relationship of quality and quantity of flows into Hubbard Creek Reservoir reduces the overall effect of low flow chloride loadings on the reservoir. For example, during the 1972 water year, from October 1971 thru September 1972, the total flow measured at Station 8-0862.12 was 4,451 acre feet. Total chloride loading at this station was 2,500 tons. Flows under 10 cfs were experienced 91.2 percent of the time and contributed only 25 percent of the chloride loading measured at the station.

Low flows that are caused by subsurface seepage appear to be associated with flows under 2 cfs. Flows under 2 cfs contributed only 8.9 percent, or 225 tons, of the chloride loading measured at Station 8-0862.12 during the 1972 water year.

It does not appear that efforts to reduce chloride pollution of Hubbard Creek Reservoir by eliminating highly chlorinated low flows will make significant improvements in the water quality of the reservoir.

SECTION IX

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